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JOINT COUNTERAIR AND THEATER MISSILE DEFENSE DOCTRINE TO DEFEND AGAINST UNMANNED AERIAL SYSTEMS AND CRUISE MISSILES IN ASYMMETRIC WARFARE

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Table of Contents

I. Introduction

The overwhelming military victory by the United States and coalition forces against Iraq during Operation Desert Storm in 1991 triggered several tactical and technological transformations in the way we plan, equip and train our forces to conduct Counter-air and Theater Missile Defense (TMD). The ability of the coalition air forces to achieve and maintain air superiority over Iraqi air space within days of the opening salvos enabled coalition ground forces to operate in an austere environment where the only threat from the air was in the form of scud missile attacks. The Iraqi scud missile attacks on Israel, Saudi Arabia and Kuwait received notable attention as did the Army Patriot missiles which successfully intercepted several of the incoming Scuds. However, the scud missile attack on the US barracks in Dhahran, Saudi Arabia on February 25, 1991 that killed 29 soldiers and wounded another 99 reemphasized the need for a more robust Theater Ballistic Missile Defense (TBMD) capability.

Since Desert Storm, the Missile Defense Agency (MDA) has invested billions of US tax payer dollars on upgrading its ballistic missile defense capability. The Ballistic Missile Defense program will encompass an integrated, layered defense system featuring X-band radars, space based sensors and surface/ground based interceptors. The Army's Patriot Air Defense System which gained notoriety during Desert Storm will be complemented by the Terminal High Altitude Area Defense (THAAD) system. THAAD will provide the US Army with an extended range hit to kill capability out to 200km with an altitude upwards of 150km. The US Army has also made significant upgrades to its Patriot Advanced Capability-3 (PAC-3) system to enhance its effectiveness. PAC-3 with range up to 45km and a max altitude up to 15km and THAAD will provide a layered defensive umbrella against Theater Ballistic Missiles. Since the first gulf war, the Navy has also enhanced its theater ballistic missile defense capability. It has

demonstrated its ballistic missile defense capability during several successful firings of the Standard Missile-2 (SM-2) and Standard Missile-3 (SM-3) from Aegis cruisers and destroyers against ballistic missile targets. The SM-2 provides a medium range, and the SM-3 provides an extended range, ballistic missile defense capability. The Aegis BMD capability was highlighted in Feb 2008 when an SM-3 from the USS Lake Erie shot down an errant spy satellite that threatened to crash to Earth with its highly toxic hydrazine tank still intact.

On the other end of the spectrum, the absence of an air breathing threat to US ground forces during Desert Storm and subsequent operations facilitated a reduction in Army and Marine Corps short range ground based air defense assets. Other than the Patriot/Scud engagements, no other ground based air defense unit that deployed to Desert Storm engaged a hostile air threat. Subsequently, the Marine Corps completely phased out its medium altitude air defense capability utilizing the Hawk Missile System, and reduced its Low Altitude Air Defense (LAAD) capability incorporating the Stinger Missile System by 60% from pre-Desert Storm numbers. The Army has also divested itself of a low-to- medium altitude ground based air defense capability and similarly reduced its complement of Stinger units.

Following Desert Storm the main focus of effort has been on Theater Ballistic Missile Defense, with the implied assumption that fixed wing aircraft will achieve air superiority and provide an air defense umbrella for ground forces by conducting offensive counter air operations (OCA). However, there are two emerging threats which could seriously put this capability to the test. Rogue nation states such as Iran and North Korea, and terrorist organizations such as Hezbollah and Al-Qaeda, have either acquired or are in the process of developing or acquiring Unmanned Aerial Systems (UAS) and cruise missiles.

This paper will examine if the United States and its alliances are adequately prepared to counter the emerging Unmanned Aerial System and Cruise Missile threat by rogue state actors and terrorist organizations. Furthermore, it will review emerging technological developments to counter the threat and examine if there is a congruency in technology and doctrine for Counter-air and Theater Missile Defense.

II. Background

> *"Could not explosives even of the existing type be guided automatically in flying machines by wireless or other rays, without human pilot, in ceaseless procession upon a hostile city, arsenal, camp, or dockyard?"* [1]
>
> Winston Churchill 1925

The use of cruise missiles and UASs in warfare is not a new phenomenon. According to an unknown source as published in Joint Publication 3-01.5: *Doctrine for Joint Theater Missile Defense*, it is reported that in 1925 Winston Churchill questioned whether the viability of an unmanned aerial weapon system could be used could be used against industrial areas, cities and ports. Churchill got the answer to his question twenty one years later when on 12 June 1944, Germany launched the first ten V-1 Flying Bombs at England. Over the next few months, over 1,400 V-1 and V-2's would hit England.

Although the cruise missile threat has been a legitimate threat since the first V-1/V-2 launches in 1944, the United States has held a monopoly on this technology throughout the remainder of the twentieth century. Since 1990, the United States has used cruise missiles extensively in Iraq, Bosnia and Afghanistan. Over "400 Tomahawk Land Attack Missiles (TLAMs) were fired by surface vessels and submarines during Desert Storm and subsequent

[1] Joint Publication 3-01.05, *Doctrine for Joint Theater Missile Defense.* 22 February 1996.

operations in Iraq, and in Bosnia during Deliberate Force in 1995".[2] An additional "39 Conventional Air Launched Cruise Missiles (CALCM) from seven B-52's launched from Barksdale AFB, LA were at fired high-priority targets in Iraq" in January 1991.[3] The United States Air Force also used BQM-74C drones to "simulate attacking aircraft in order to locate and target Iraqi air defense fire control radars."[4] This is a tactic that could also be utilized by an adversary to locate and target friendly forces and will need carefully assessed when developing doctrine to counter the cruise missile threat.

Unmanned Aerial Systems have also been used predominantly by the United States and coalition forces since 1990. During Desert Storm, the Pioneer Unmanned Aerial Vehicle (UAV) flew "522 sorties to provide targeting information for naval gunfire, B-52 bombing runs and provide mapping information to steer Tomahawk cruise missiles to their targets." [5] While the Pioneer provided targeting and imaging information, follow-on systems such as the Predator, Reaper and Global Hawk provide much more robust capabilities, including the capability to fire precision guided munitions such as the Hellfire missile.

Since the end of the cold war, the proliferation of UAS and cruise missile systems and technology has spread around the world. Without a peer competitor who can rival US air power, potential adversaries are likely to pursue an asymmetric strategy to alter the balance of power. The ballistic missile threat is a serious concern when confronting rogue state actors such as Iran or North Korea, but Theater Ballistic Missiles (TBM's) are too costly, too hard to conceal and

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[2] Military Analysis Network. *BGM-109 Tomahawk*. http://www.fas.org/man/dod-101/sys/smart/bgm-109.htm. 30 May 2008.

[3] Military Analysis Network. *AGM-86C Conventional Air Launched Cruise Missile*. http://www.fas.org/man/dod-101/sys/smart/agm-86c.htm. 8 May 1999.

[4] National Museum of the USAF. *Northrop BQM-74C Fact Sheet*. http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=416.

[5] PBS Home. *Frontline: The Gulf War*. http://www.pbs.org/wgbh/pages/ frontline /gulf/ weapons/ drones.html. 9 January 1996.

much more difficult to acquire to be a viable weapon for a terrorist organization. Cruise missiles are likely to become the terror weapon of choice by non-state actors since they are lethal, reliable, hard to detect, and relatively inexpensive.

III. Categories of Unmanned Aircraft Systems

Unmanned Aerial Systems come in multiple configurations and can perform a multitude of missions from reconnaissance and weapons delivery. They can be propeller, rotary wing or jet propelled. All UASs are unpiloted aircraft that can be flown remotely or autonomously on a pre-programmed flight path. By definition, cruise missiles fall under the category of UASs but will be discussed as a separate entity in this paper due to their unique characteristics and capabilities. For clarity sake, the term UAS will be used throughout the document and are defined as recoverable multirole aircraft also known as Unmanned Aerial Vehicles (UAV) , whereas cruise missiles are unrecoverable aircraft designed to perform a single strike mission. Both UASs and Cruise missiles present a difficult targeting solution due to their small radar cross section, and low infrared signatures.

IV. Threat

"Many countries remain interested in developing or acquiring land-attack cruise missiles, which are almost always significantly more accurate than ballistic missiles, and complicate missile defense systems. Unmanned aerial vehicle are also of growing concern."[6]

George Tenant in testimony before Senate Select Committee on intelligence. February 2004

Over the last twenty years, significant advances accuracy, range, lethality and reliability have made cruise missiles a viable weapon system. The current generation of cruise missiles

[6] Eugene Miasnikov. *Threat of Terrorism Using Unmanned Aerial Vehicles, Technical Aspects.* Center for Arms Control, Energy and Environmental Studies at MIPT. June 2004.

incorporating stealth technologies can fly undetected into heavily defended areas and deliver a devastating payload without putting a pilot in harm's way. For these reasons cruise missiles are a fundamental component of the United States military's deep strike capability. For these same reasons, cruise missiles have become an attractive weapon system for our potential adversaries.

The threat posed by cruise missiles and armed UAS's in the hands of rogue nations and non-state actors to forward based troops has grown exponentially over the last decade. Currently there are over 10,000 UAS's and cruise missiles in global inventories, exported by countries such as Russia, China, Iran, North Korea and South Africa. These systems range from primitive remote controlled model aircraft modified with an optical sensor to sophisticated air-launched or land-launched cruise missiles such as the Chinese C802 and silkworm anti-ship missiles. Compounding this threat is that, in addition to conventional warheads, many of these systems either possess the capability or are under development to deliver weapons of mass destruction.

Cost is another factor which makes cruise missiles an attractive choice for potential adversaries. The cost of a cruise missile can range anywhere from $50,000 upwards to over $1,000,000. The most technologically advanced cruise missile pales in comparison to the costs associated with acquiring and maintaining a fleet of manned fighters and/or bombers. Cruise missiles are also a cost effective choice over ballistic missiles which can cost five to seven times as much. Table I. is a small sample of some of the cruise missiles, their ranges and payloads that currently exported worldwide.

System	Country	Launch Mode	Warhead Type	Maximum Range (miles)
Chinese cruise missile	China	Undetermined	Conventional or nuclear	Undetermined
APACHE-A	France	Air	Conventional/ sub munitions	100+
SCALP-KG	France	Air and ship	Conventional/ penetrator	300+
KEPD-350	Germany/Sweden/Italy	Air and ground	Conventional/ unitary	220+
KEPD-150	Germany/Sweden/ltaly	Air and ship	Conventional/ unitary or sub munitions	100+
Popeye Turbo	Israel	Air	Conventional/ unitary	200+
AS-15	Russia	Air	Nuclear	1,500+
SS-N-21	Russia	Submarine	Nuclear	1,500+
Russian conventional cruise missile	Russia	Undetermined	Conventional/ unitary or sub munitions	Undetermined
MUPSOW	South Africa	Air and ground	Conventional/ unitary or sub munitions	125+
Storm Shadow	United Kingdom	Air	Conventional/ penetrator	300+

Table I: Land Attack Cruise Missiles[7]

In addition to cruise missiles, Unmanned Aerial Systems are also likely to become a weapon of choice for terrorist organizations and rogue states. UASs can be either armed or unarmed. Unarmed UASs can be used for reconnaissance, surveillance, target acquisition and designation. The lethality and precision strike capability of armed UASs such as the US Predator & Reaper UASs firing hellfire missiles in Iraq and Afghanistan has been well documented.

UAS's can range in size from micro-UASs which are about the size of an orange and can weigh less than a pound to the size of manned aircraft. Defense against UASs in-flight is a

[7] National Air Intelligence Center NAIC-1031-0985-98, "*Ballistic and Cruise Missile Threat*", www.fas.org/irp/threat/missile/nais/part07.htm.

challenge for conventional air defense systems due to the UAS's low observable/low radar cross section and low infrared (IR) signature characteristics. Table II represents some of the UASs, range and payload that currently in service around the world.

Type	Country	Range (KM)	ALT (M)	PAYLOAD
HARPY	ISRAEL	500	UNK	HE
ABABIL-T	IRAN	UNK	4270	HE
ASN-206	CHINA	150	6000	EO/IR
MOHAJER IV	IRAN	150	1829	EO/IR/EW
NISHANT	INDIA	161	3658	EO/IR
DR-3	RUSSIA	70	1000	EO/IR

Table II: Unmanned Aircraft Systems[8]

V. Current Joint Doctrine

"*Joint counterair operations are executed by all components, using a variety of integrated weapon systems and sensors to counter threats, both before and after launch.*"[9]

The proliferation of cruise missile and low observable/low radar cross-section (LO/LRCS) systems presents the Joint Force Commander (JFC) with a multitude of issues and concerns for the integration of theater missile defense capabilities to support the JFC campaign plan. Joint Publications 3.01 and 3-01.5 *Joint Doctrine for Countering Air and Missile Threats* and *Doctrine for Joint Theater Missile Defense* respectively, provide the overarching planning guidance for countering these threats.

[8] Larry Marotti., *Threat of Unmanned Aerial Vehicle Systems against U.S. Ground Forces*. U.S. Army Logistics Management College, Ft Lee, VA. 12 October 2005.

[9] Joint Publication 3-01, *Countering Air and Missile Threats.* 05 February 2007. IX.

Joint Publication 3-01.5 defines Joint Theater Missile Defense as "the integration of joint force capabilities to destroy enemy theater missiles in flight or prior to launch or to otherwise disrupt the enemy's theater missile operations through an appropriate mix of mutually supportive passive missile defense, active missile defense, attack operations, and supporting command, control, communications, computers, and intelligence (C4I) measures."[10] Joint Publication 3-01.5 further defines these operational elements as follows[11]:

1. Passive defense - measures taken to posture the force to reduce vulnerability and minimize the effects of a TM attack.

2. Active defense - operations taken to protect against a TM attack by destroying TM airborne launch platforms and/or destroying TM's in flight.

3. Attack operations - operations taken to destroy, disrupt, or neutralize TM launch platforms and their supporting structures and systems.

4. Command, Control, Communications, Computers and Intelligence (C4I) - systems used to coordinate and integrate the joint force capabilities to conduct and link passive defense, active defense and attack operations.

None of these operational elements can stand alone as an effective defense against the advancing technology of today's theater missile threat. JCS planners must coordinate and integrate each element in development of their operations plan. Two of these operational elements, Passive Defense and Attack operations fall outside the scope of this document. Passive defense are measures based on the theater missile threat assessment that must be taken at all echelon levels of command to reduce the vulnerability of missile attack. Offensive counter air or attack operations such as the "Scud hunts" that garnered much media attention during the first

[10] Joint Publication 3-01.05, *Doctrine for Joint Theater Missile Defense.* 22 February 1996, 1-3.

[11] Ibid, Joint Publication 3-01.05, 1-4.

Iraqi war are directed towards the ballistic missile threat rather that the LO/LRCS threat presented by cruise missiles and UASs.

Joint Publication 3-01.5, *Doctrine for Joint Theater Missile Defense (JTMD)*, defines the Theater Missile (TM) threat as "ballistic missiles, cruise missiles, and air to surface missiles whose targets are within a given theater of operations"[12]. The JTMD definition doesn't include UASs in their threat profile since they are technically not a missile but a reusable aircraft. Countering UASs falls under the same auspices as countering conventional fixed wing and rotary wing aircraft and is incorporated in Joint Publication 3.01 *Joint Doctrine for Countering Air and Missile Threats.* However, in terms of difficulty in detection and targeting, UASs possess challenges more similar to cruise missiles than conventional aircraft.

Joint Doctrine further defines Theater Missile Defense Systems as "systems with applicable capabilities that may be used to support passive missile defense, active missile defense, attack operations, and supporting command, control, communications, computers, and intelligence (C4I) and countermeasures required to counter the missile threat."[13] The remainder of this paper will focus on the active air defense and C4I operational elements of JTMD and determine if existing and emerging joint capabilities are in congruence with established doctrine.

VI. Current Engagement Capabilities & Limitations

"Anybody, in my opinion, has the ability to make a very inexpensive cruise missile. It is not a matter of technology. It is just a matter of when it is going to happen. So, we just have to decide when (and how) we are going to be ready to deal with that situation."[14]

Gen. John Jumper, USAF (Ret.)

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[12] *Joint Publication 3-01.05, Doctrine for Joint Theater Missile Defense. 22 February 1996, 8.*

[13] *Ibid, Joint Publication 3-01.05, 8.*

[14] *Amy Butler, Low, Slow and Stealthy*. Aviation Week & Space Technology. 11 June 2006.

General Jumper's statement to Air and Space Weekly in 2006 continues to be the burning question two and a half years later. Historically each of the four services has had their own stove-piped air defense capability providing point defense for a limited geographic area. Current surveillance systems include the Air Force E-3 AWACS and Navy E-2 Hawkeye, providing airborne surveillance and cuing to front line fighter aircraft equipped with look-down/shoot-down capability. The Marine Corps AN/TPS-59 radar provides long range target surveillance for air-breathing and ballistic missile defense cuing. Navy Aegis cruisers and destroyers provide shipborne missile defense and the Army provides a ground based air defense capability with their Patriot units. However, none of these existing systems in their current configuration are in compliance with current joint doctrine for active air defense.

Effective active air defense of cruise missile and Unmanned Aerial Systems requires the ability to detect, identify and destroy the target as far away as possible from forward deployed troops, bases, ships, defended civilian populations and other vital areas. Early detection of cruise missiles and other low observable/low radar cross section targets before they reach their intended target is the greatest challenge to the air defender. Cruise missiles incorporating terrain following/terrain masking flight profiles present early detection obstacles for both ground based and airborne surveillance platforms. Ground based radar detection capability is limited by the curvature of the earth and natural obstacles such as hills and valleys. Traditional airborne surveillance systems also have difficulty detecting low flying, low observable aircraft due to ground clutter. Space based sensors provide limited capability of detecting cruise missiles and low flying UASs. Satellite assets have difficulty detecting cruise missiles (and UAS), through dense cloud cover. Unlike ballistic missiles, which break through the highest bands of clouds, the low flying nature of cruise missiles enables them to use the cloud deck as cover from space-

based detection.[15] AWACS and Hawkeye cuing to fighter aircraft with lookdown-shootdown radar is currently the most effective capability to detect, track and destroy cruise missiles and other UASs.

Once a cruise missile or other low observable/low radar cross section object has been detected, the battlefield management command and control agency will need to positively identify the target as hostile in accordance with the standing rules of engagement and current weapons release conditions. Timely identification is best accomplished through positive and procedural control of the airspace. In accordance with Joint Pub 3-01, "Airspace control is provided to reduce the risk of friendly fire, enhance air defense operations and permit greater flexibility of operations."[16] Airspace coordination measures combined with an integrated system of radars, Identification Friend or Foe (IFF) and data links provides for the accurate and timely ID of enemy aircraft and missiles. It is reliant on a robust, reliant and secure command, control communication, computers and intelligence (C4I) network for timely exchange of information. While current systems and procedures provide an adequate capability to identify enemy aircraft and missiles, it has its flaws as witnessed by the numerous "friendly fire" incidents during recent conflicts.

Once a target has been detected and positively identified as hostile, Air Force, Marine Corps and Navy fighter aircraft provide the best, albeit limited capability to destroy a cruise missile in flight. Detection of UASs is also a challenge due to their size and limited IR signature. However, since their flight characteristics are similar to traditional air breathing threats, once

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[15] Jeff Kueter and Howard Kleinberg. *The Cruise Missile Challenge: Designing a Defense Against Asymmetric Threats.* Washington DC: The George C. Marshall Institute. 3 May 2007, 34.

[16] Joint Publication 3-01, *Countering Air and Missile Threats.* 05 February 2007, 3-3.

detected the chances of a successful engagement by air to air or surface to air missiles is incrementally improved.

Even after a target has been successful detected and identified, the current capability to intercept a cruise missile is a significant weakness of U.S. Joint Doctrine for active air defense.

a. Fighter Aircraft: Current frontline fighters with Advanced Medium Range Air to Air Missiles (AMRAAM) and look-down, shoot-down radar such as the Air Force F-15 and Navy F/A-18 Super Hornet provide the best U.S. capability to engage a cruise missile in flight.

b. Patriot Missile System: The Patriot Surface to Air Missile System was originally designed in the 1960's to engage medium to high altitude Soviet aircraft at speeds up to Mach 2, but the latest variants, Patriot Anti Cruise Missile (PAC-2) and Patriot Advanced Capability-3 (PAC-3) have been upgraded to engage cruise and ballistic missiles respectively. Patriot's capability to shoot down ballistic missiles such as Iraqi scuds during Operation Desert Storm was well documented, but its capability to shoot down a cruise missile has not been demonstrated in combat. During the Iraq war in 2003, five crude Iraqi cruise missiles managed to evade U.S. Patriot Missile Defenses.[17]

c. AEGIS: Aegis cruisers and destroyers provide cruise missile defense capability as part of their shipborne theater missile defense using the SM-2, SM-3 and SM-6

[17] Center For Defense Information. *Missile Defense: The Patriot Missile Defense System in Iraq: Newly-released Army History Raises Serious Questions*. http://cid.org/friendly version/printversion.cfm?documentID=1798. 22 October 2003.

missiles, the RIM-116 Rolling Airframe Missile (RAM) and Phalanx Close-In Weapon System (CWIS) radar controlled 20mm gun for battlegroup and ship defense.

d. Stinger Missile: The Stinger reprogrammable microprocessor (RMP) PAC-1 surface to air missile system provides short range, close in, very limited defense capability against UASs and cruise missiles.

VII. Concepts and Emerging Technologies

Each of the four services has either existing capabilities, or on-going missile defense programs that can contribute to a Joint Theater Missile Defense (JTMD) capability. The Navy's Sea Shield and Force Net programs will provide over the horizon engagement capability against cruise missiles deep inland. The Marine Corps AN/TPS-59 and Ground/Air Task Oriented Radar (G/ATOR) sensors and Cooperative Engagement Capability (CEC) provide surveillance and C2 integration. The Army, which currently relies on the Patriot missile system for cruise missile defense will significantly augment this capability when the Joint Land Attack Cruise Missile Defense Elevated Netted Sensor (JLENS) and Surface Launched Advanced Medium Range Air to Air Missile (SLAMRAAM) programs are fielded. Continued fielding of the F/A-22 Raptor will boost the Air Force's capability to defeat both cruise missiles and low observable UASs.

Sea Shield: Sea Shield, along with Sea Strike and Sea Basing, is one of the three fundamental concepts of the Navy's Sea Power 21 transformation strategy. Sea Shield represents a paradigm shift from focusing on protecting the fleet to projecting defensive capabilities to protecting coalition and joint forces ashore. A pillar of Sea Shield is Navy Theater Air and Missile Defense (TAMD) which will provide an over the horizon at sea or deep inland detection

and engagement capability against all forms of aircraft and ballistic or cruise missile threats. [18] The Navy's TAMD program initiatives will feature sensor upgrades to the Aegis, E-2C Hawkeye and F/A-18E/F platforms, a fully integrated network providing a single integrated air picture and over-the-horizon ship launched missiles. In accordance with joint doctrine, the Navy TAMD system will integrate its capabilities with other service capabilities as an element of the Joint TAMD system.

ForceNet: ForceNet is the network centric warfare (NCW) integration component of the Sea Power 21 transformation plan. "ForceNet is the plan for making NCW an operational reality: it will integrate warriors, sensors, command and control, platforms and weapons into a networked, distributed combat force." [19] ForceNet will merge existing capabilities with emerging technologies such as Cooperative Engagement Capability (CEC), the Naval Fires Network (NFN) and the Expeditionary Sensor Grid."[20]

Joint Land Attack Cruise Missile Defense Elevated Netted Sensor **(**JLENS**):** The Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System will provide over the horizon detection and tracking of aircraft (manned and unmanned) and cruise missiles. An Army system with a projected Initial Operational Capability (IOC) of 2013, JLENS is a system of two tethered aerostats operating at altitudes up to 12,000. JLENS will provide 360 degree surveillance and can overcome line of sight and terrain masking limitations inherent in ground based radar systems. The sensor suite for the two aerostats consist of a surveillance radar (SuR) and a fire control radar (FCR) that are capable of tracking multiple targets simultaneously. In a joint environment, the surveillance radar can provide air breathing and cruise missile data via Link-16 to the single integrated air picture. The JLENS Fire Control Radar can provide track

[18] Admiral Vern Clark. *Sea Power* 21, Proceedings, The Naval Institute, 17.
[19] Peter Dombrowski and Andrew Ross. "Transforming the Navy", Naval War College Review, Summer 2003, 8.
[20] Ibid., 12.

and ID data to support multiple missile systems including the Navy Standard Missile 6 (SM 6), Air Force AMRAAM, and Army Patriot PAC-3.

Surface Launched Advanced Medium Range Air to Air Missile (SLAMRAAM): The Army is currently developing the Surface Launched Advanced Medium Range Air to Air Missile (SLAMRAAM) system designed to defeat the current and emerging cruise missile and UAS threat. The SLAMRAAM system will consist of a launcher with up to six AIM-120C AMRAAM missiles mounted on a High Mobility Multipurpose Wheeled Vehicle (HMMWV). It will provide enhanced capability over the Stinger missile system by providing beyond line of site, day or night engagement capability at extended ranges. The SLAMRAAM system will incorporate an Integrated Fire Control System (IFCS) to provide critical target cuing information. The IFCS for SLAMRAAM provides Battle Management Command, Control Computers, Communications, and Intelligence (BMC4I) by developing a fire control solution from information provided by one or more organic or non-organic sensor sources.

RADAR Modernization Program (RMP)**:** The Air Force's Radar Modernization Program features an Active Electronic Scan Array (ASEA) radar and improved electronics to enhance the capability of current front line fighter aircraft to detect and track small targets such as cruise missiles and UASs. Currently the Navy's newest F/A-18 E/F Super Hornet and the Air Force F-15C's are equipped with the APG-79 ASEA radar and selected squadrons of Air Force F-16 and F-15E have been approved for ASEA upgrades. Next generation fighter aircraft such as the F-22 Raptor and F-35 Joint Strike Fighter will be equipped with an AESA radar as part of their sensor suite.

Some other systems that have potential, but to date an unproven cruise missile defense technologies are directed energy weapons such as the Airborne laser (ABL), the Tactical High

Energy Laser (THEL), and the Counter Rocket, Artillery and Mortar (C-RAM) radar guided gun system.

Airborne laser: The Airborne Laser (ABL) is a directed energy weapon system currently under development by the Air Force. Mounted on a 747, the Airborne Laser uses "two solid state lasers, and a megawatt-class Chemical Oxygen Iodine Laser (COIL) to detect, track, target, and destroy ballistic missiles shortly after launch during the boost phase."[21] After detecting the missile launch and acquiring the target, the ABL fires its laser for up to eight seconds. The laser heats up and weakens the missile skin causing in-flight failure. Although the ABL is designed to shoot down ballistic missiles, it may provide an inherent but untested capability to shoot down cruise missiles.

Tactical High Energy Laser (THEL)**:** THEL is a joint U.S – Israeli program that "uses proven laser beam generation technologies, proven beam pointing technologies, and existing sensor and communication networks to provide an active defense capability in counter air missions."[22] A mobile variant of THEL is also currently under development. A potential system which is not currently being funded but could potentially provide a very effective cruise missile defense capability would be a tethered laser system. Such a system would be technically challenging due to weight and power constraints associated with mounting a laser on an aerostat.

Radar Guided Gun System: Currently there is no Department of Defense funded project for the development of land based radar guided gun system to provide a cost effective close in air defense capability against cruise missiles and UASs. However, the Army is currently investigating the potential use of a land based version of the Phalanx Close in Weapon System

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[21] Missile Defense Agency. *The Airborne Laser*. Missile Defense Agency Fact Sheet. Washington, DC. June 2008.

[22] Wikipedia. *Tactical High Energy Laser*. http://en.wikipedia.org/wiki/ Tactical_High_Energy_Laser.12 July 2008.

(CWIS) which can fire 3,000 to 4,500 20 mm rounds per minute for counter battery fire against rockets, artillery and mortars. If this system was capable of receiving network centric targeting cuing from an Integrated Fire Control System, it could provide a formidable capability for self-defense of cruise missiles and UASs at close range. A system such as this could be used for point defense at forward operating bases, logistic sites or other vital areas. The possibility also exists for a mobile variant for defense of forward based troops.

VIII. Conclusion

Since Operation Desert Storm in 1991, much more focus has been placed on Ballistic Missile Defense initiatives than on defending against the cruise missile and UAS threat. However, these weapons pose a higher and more likely threat to forward deployed troops. Cruise missiles are a likely to become the weapon of choice to shift the balance of power in asymmetric warfare since they are cost effective, difficult to detect, hard to destroy in flight and capable of delivering conventional munitions and/or Weapons of Mass Destruction (WMD).

The current existing capability to defend against cruise missiles is deficient as demonstrated by Iraq's successful launch of five cruise missiles against US forces during the early stages of Operation Iraqi Freedom that were undetected by US air defenses. AMRAAM equipped fighters and Patriot missile batteries are capable weapon systems but whose effectiveness is limited when acting independently. Recognizing this emerging threat in 2002, former Secretary of Defense Donald Rumsfeld directed that the cruise missile defense program be moved under the guidance of the Missile Defense Agency (MDA). The Army, Air Force and Navy are on-board with developing an integrated, layered, network centric joint capability to detect and destroy cruise missiles. The Navy's Sea Shield and ForceNet initiatives, building

upon existing technologies will provide network centric warfare functionality in the joint arena. Fifth generation fighters such as the F-22 and F-35 along with sensor upgrades on current front line fighters provide the Air Force with improved interceptor capabilities. SLAMRAAM will provide an enhanced short to medium range ground based interceptor capability for the Army to augment their Patriot PAC-2 and PAC-3 units. One consideration that needs to be assessed is the disproportionate cost tradeoff between threat weapon systems and the proposed interceptors. With a price tag of over $1M per interceptor such as Patriot, THAAD or SM-6, are not be the most efficient means to counter this threat. SLAAMRAM offers a more cost effective solution at $300,000 per missile and a radar guided gun system for land forces should also be thoroughly assessed.

JLENS will provide robust over the horizon surveillance and targeting information to a host of interceptors in the joint arena, but also has several limitations. The logistic footprint for JLENS is massive. In addition to the two 74 meter aerostats, the system includes three shelters, a Communications and Control Station (CCS), a Data Processing Station (DPS) and a Signal Processing Station (SPS), a 112 foot, 80 ton mobile mooring station and associated ground support equipment. This asset will not be available in a forced entry environment until at least D+30 leaving expeditionary forces vulnerable during the forced entry phase of an operation.

The Marine Corps is the one service will continue to lack any organic creditable defensive counter-air capability. Other than incorporating its sensor data into the single integrated air picture, the Marine Corps has deferred the TMD role to the Army and Navy. This is a critical vulnerability for expeditionary forces in harms way that could be exploited by an adversary.

Whereas emphasis on cruise missile defense has gained some momentum in recent years, albeit still lagging behind ballistic missile defense, countering the emerging threat of unmanned aircraft systems has flown under the radar. Joint Pub 3-01 identifies Unmanned Aircraft Systems as a primary asset that could be utilized for the Offensive Counter Air (OCA) mission. It also recognizes UAS as a potentially formidable threat to friendly forces, noting their capability to conduct surveillance/reconnaissance and attack missions. Joint Pub 3-01 further recognizes the challenges faced by existing sensors and early warning systems in detecting UAS due to their small size and unique flight characteristics. Other than recognizing UAS as an emerging threat, no other doctrine or Department of Defense initiatives have been focused countering the threat. The implied assumption is that the same tactics, techniques and procedures to counter manned aircraft will be applied to counter unmanned aircraft systems.

IX. Recommendations

Since the United States currently has no peer competitor, asymmetric warfare and counter terrorism operations are the most likely modes of conflict confronting friendly forces in the near future. Cruise missiles and other low observable/low radar cross section unmanned aerial systems will likely be the weapon of choice over ballistic missiles. The United States needs to shift assets, priorities and focus doctrine to counter this emerging threat. Joint doctrine still maintains that the key to successfully countering these threats will be to gain and maintain air superiority be accomplished through an integrated effort of offensive and defensive counter air (OCA/DCA) operations. Achieving air superiority in an asymmetric threat environment will be a challenge. Continued emphasis on developing a layered, fully integrated air defense system

focused on detecting, identifying and engaging low observable/low radar cross section aircraft and missiles is essential.

Near-term enhancements provide improved cruise missile defense capability but still leave forward deployed troops vulnerable. The Navy's Sea Shield and the Army's mix of sensors and interceptors will improve this defensive capability. Once fielded and deployed, JLENS will provide an outstanding capability for detecting and targeting cruise missiles and UASs contributing to the single integrated air picture for theater missile defense. An alternative solution to JLENS, at least in support of expeditionary forces during the early stages of a conflict would be to equip a high altitude-long endurance UAS with a missile warning sensor capable of down-linking target data to ground based air defense or air-to-air interceptors. Another possibility may be a pair of UASs operating in tandem as a hunter-killer team with one UAS carrying the sensor and the other a shooter equipped with either a missile or an airborne laser. The Department of Homeland Security (DHS) is currently evaluating a similar capability of equipping a UAS with a missile warning system for domestic airport security.

The Marine Corps is taking a calculated risk in its expectations that the Army or Navy will be available to provide the TMD umbrella for its expeditionary forces and need to revitalize its organic air defense capabilities as an element of the Joint Theater Missile Defense architecture.

X. Glossary

AESA: Active Electronically Scanned Array

CALCM: Conventional Air Launched Cruise Missile

CEC: Cooperative Engagement Capability

CIWS: Close In Weapon System

DCA: Defense Counter Air

G/ATOR: Ground/Air Task Oriented Radar

JTMD: Joint Theater Missile Defense

LAAD: Low Altitude Air Defense

MDA: Missile Defense Agency

OCA: Offensive Counter Air

PAC-3: Patriot Advanced Capability-3

RMP: Radar Modernization Program

RMP: Reprogrammable Microprocessor

SLAMRAAM: Surface Launched Advanced Medium Range Air to Air Missile

SHORAD: Short Range Air Defense

SM-2/3/6: Standard Missile

THAAD: Terminal High Altitude Area Defense

TLAM: Tomahawk Land Attack Missile

TMD: Theater Missile Defense

TBMD: Theater Ballistic Missile Defense

UAS: Unmanned Aerial Systems

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